WAVE CALCULATION USING WAM MODEL AND NMC WIND[1]

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Abstract

The CYCLE 2 version of the WAM (Wave Model) model is used to hindcast global ocean wave spectra, using the NMC (National Meteorological Center) winds, for a period of about 60 days. The results of the WAM waves and the NMC winds are compared with the NDBC (National Data Buoy Center) buoy data and the results of other models. The comparison indicates that although the WAM model predicts low estimates of the significant wave height when compared with the buoy data, its accuracy is slightly more favorable than the other models. However, the CPU time from the WAM model is about ten times longer than the other models.

Introduction

Ever-increasing human activities in the ocean have made it clear that accurate understanding and prediction of wind waves are essential to the safety and success of engineering design in coastal and offshore waters. During the last four decades, the state of the art in wind wave modeling and prediction has advanced to such a stage that numerical models are used not only for forecasting and rational engineering design but also for the understanding and verification of the mechanics involved in wave evolution. Nevertheless, at present some of the mechanics, such as dissipation, generation, and the air-sea coupling, are still incompletely understood and remain a challenging undertaking for both research and development.

The WAM model has been used for wind wave prediction and the study of wind wave evolution mainly in the European research community. The model includes the most recent parameterizations of wave generation due to wind, wave dissipation due to wave breaking and bottom friction, and wave energy transfer due to a resonant quartet of waves (nonlinear wave-wave interactions). Only the WAM model has a more complete implementation of the nonlinear interaction; in all other wave models this mechanism is either absent or incompletely implemented. In this study, performance of the WAM model is examined. The WAM model is run for the global oceans

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during November 1989 through January 1990, using the NMC analysis winds. Results in terms of the significant wave height, H_s, and mean wave direction and period, T_m, are compared with the NDBC buoy data and the results of the NOW (NOAA Ocean Wave Model), GSOWM (Navy's Global Spectral Ocean Wave Model), and NROW (NOAA Regional Ocean Wave Model) wave models.

WAM Model

The WAM model was originally developed by Hasselmann (Hasselmann 1987) and has been steadily improved by the WAM Development and Implementation (WAMDI) Group led by Hasselmann (The WAMDI Group 1988). The model is classified as a third generation wave spectral model because it includes nonlinear wave-wave interactions. The model is based on a field solution of the radiative transport equation which is the wave action equation. It includes refraction, shoaling, and source functions for wind input, nonlinear transfer, and wave dissipation. The wind input source function is adapted from Snyder et al.(1981), but the wind velocity is replaced by the friction velocity based on the scaling of Komen et al.(1984). The nonlinear transfer source function is based on Hasselmann's equation (Hasselmann 1961) and approximated by the discrete interaction operator parameterization (Hasselmann et al 1985). The dissipation source function has two components: one is white-capping which uses the form proposed by Komen et al.(1984), and the other is bottom friction which uses the equation from JONSWAP (Hasselmann et al.1973).

The WAM model uses a finite difference scheme for solution; a first-order upwind scheme is used for the advection term, while an implicit second-order centered difference scheme is used for the source terms.

Wind

In the WAM model, sea surface wind is the only forcing function used to drive the wind waves. There are acknowledged difficulties in obtaining accurate sea surface wind fields, primarily due to low spatial and temporal resolution of the observational data. Nevertheless, the presently available wind models for wind analysis and forecasting provide reasonably accurate sea surface winds for this wind wave study. NMC analysis winds have been selected for use here. The analysis winds at 10 and 19.5 m above the sea surface are derived from the analysis winds of the lowest sigma layer of the GDAS (Global Data Assimilation System) through the use of a logarithmic profile and a correction due to air-sea temperature instability. The lowest sigma layer is within the atmospheric boundary layer just above the sea surface.

Calculation and Results

We use the NMC (3 hourly) analysis winds as input to the WAM model to hindcast 24 hour global ocean wave spectra. Daily calculations were conducted during November 1989 through January 1990. The computational grid covers the ocean region from 75S to 75N latitude, with a grid resolution of 3 degrees in both latitude

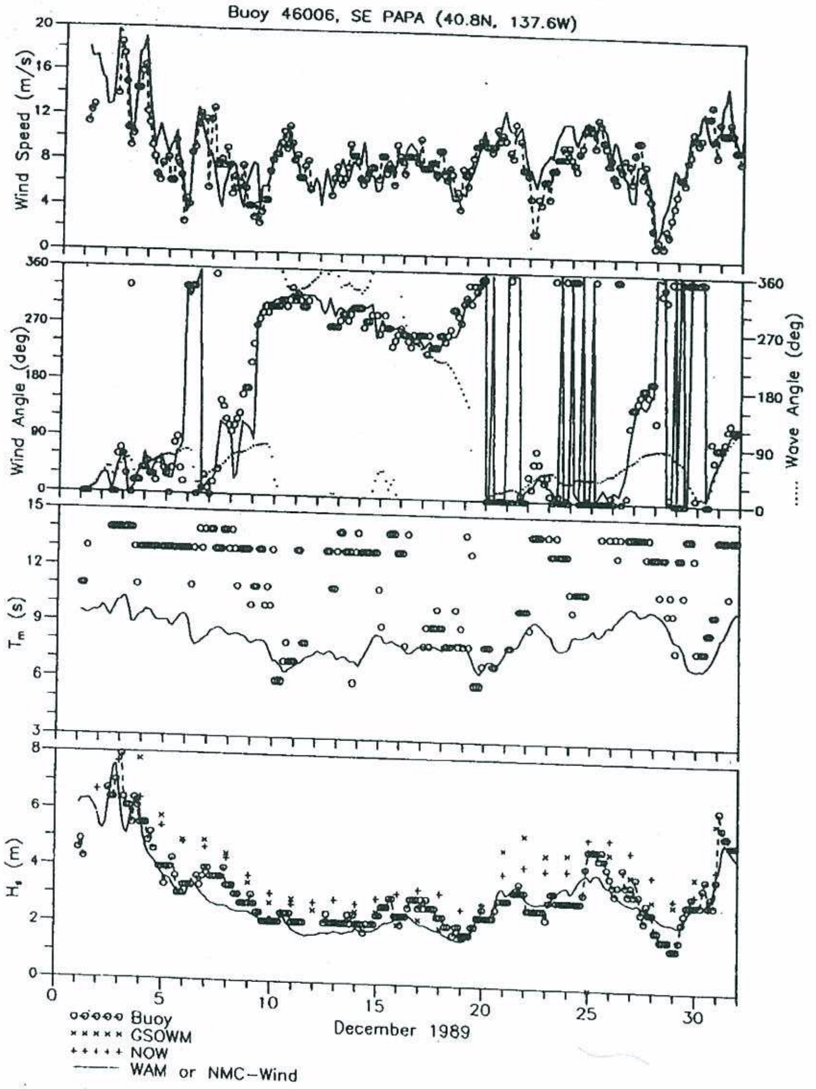

Figure 1: Time series of waves and winds

and longitude. The spectrum is represented by 25 logarithmically spaced frequencies; the ratio of frequency increment to the frequency is 0.1 and the minimum frequency is 0.042 hz . The directional resolution is 30 degrees. The integration time step is 30 minutes for both propagation and source terms. The calculation was conducted on a Cyber 205 at NMC. The CPU time for a 24 hour hindcast is about 20 minutes which is about ten times longer than the other models.

The calculated results of the WAM waves indicate that the synoptic patterns of global waves in terms of the significant wave height, H_s, and mean wave direction are generally consistent with the global winds. They are compared with the NDBC buoy data and the 24 hour forecasts of the GSOWM, NOW and NROW models, at Buoy Numbers 44004 and 41002 for the Atlantic Ocean, 42001 for the Gulf of Mexico, 46001 and 46006 for the Pacific Ocean, and 51001 near Hawaii. Results of H_s indicate that the WAM waves are slightly lower than the buoy data in most of the time series and are pronouncedly lower almost at every peak of H_s as typically illustrated in Figure 1. A study of scatterplots also confirms that the WAM H_s are slightly lower than the buoy data. The precise mechanism causing this lower prediction in H_s has not been known yet and is still under study. Nevertheless, the WAM H_s are slightly better than the GSOWM and NOW H_s. Quantitative measurements of the performance of the models are shown in Table 1. The results here indicate that the WAM performance is slightly superior to the GSOWM and NOW performance, except in the Atlantic Ocean; at Buoy 41002 where we have only limited data available during this study period. In the Gulf of Mexico, the WAM performance is inferior to the NROW's because of low grid resolution. We note that although these comparisons may be not rigorously fair because the WAM's wind input is different than the GSOWM, NOW, and NROW's, it at least shows that the WAM model is able to predict reasonably accurate global waves using the NMC analysis winds.

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Table 1: Quantitative measures of model performance

Model	n	$\overline{o}$	$\overline{m}$	σ_o	σ_m	mae	$bias$	$rmse$	ia	cor
Global										
WAM	1177	2.72	2.59	1.07	0.98	0.54	-0.13	0.72	0.86	0.78
NOW	443	2.85	2.98	1.19	0.81		0.13	0.82		0.74
GSOWM	339	2.85	3.04	1.18	1.46		0.19	0.93		0.78
Atlantic										
WAM	267	2.70	2.35	1.28	1.12	0.76	-0.35	0.96	0.84	0.76
NOW	92	2.49	2.55	1.24	0.76		0.06	0.99		0.68
GSOWM	83	2.59	2.90	1.25	1.16		0.31	0.96		0.72
Gulf of Mexico										
WAM	223	1.50	1.55	0.95	1.23	0.54	0.05	0.87	0.82	0.71
NOW	30	1.53	2.00	1.08	1.07	0.75	0.47	0.90	0.82	0.75
GSOWM	25	1.60	2.03	1.12	1.05	0.78	0.44	0.91	0.81	0.73
NROW	30	1.53	1.56	1.08	1.32	0.46	0.03	0.66	0.92	0.87
Pacific										
WAM	456	3.34	3.17	1.22	1.03	0.48	-0.17	0.62	0.92	0.88
NOW	219	3.09	3.37	1.27	1.70		0.28	1.03		0.82
GSOWM	243	3.12	3.1	1.27	0.88		0.07	0.79		0.79
Hawaii										
WAM	231	2.73	2.74	0.64	0.48	0.40	0.01	0.48	0.80	0.67
NOW	108	2.54	2.87	0.71	0.42		0.33	0.72		0.46
GSOWM	97	2.54	2.41	0.72	0.69		0.13	0.63		0.62

n = number of data; o = obs data; m = model data; overline '-'= mean;
σ = standard deviation; mae = mean absolute error;
$rmse$ = root mean square error; ia = index of agreement; cor = correlation.
length unit = meter.

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A TURBULENCE MODEL FOR TRANSVERSE MIXING IN RIVERS

by

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Abstract

A two-length-scale turbulence model is developed to simulate transverse mixing prosesses in rivers. The dispersion of the effluent from the MUC (Montreal Urban Community) sewage treatment plant in a section of the St. Lawrence River is calculated using this model. The concentration and velocity profiles obtained from the calculation are in close agreement with the field data obtained from a dye test in the river.

Introduction

Large-scale turbulent motions with a horizontal length scale significantly greater than the water depth, can be generated in a river due to variation of the river-bed topography in the longitudinal and the transverse directions. The large-scale turbulence plays a significant role on transverse mixing of pollutants and sediments across the river. However, experimental measurements of this transverse mixing process are often correlated with the local shear velocity and water depth which are the scales of the small-scale bed-generated turbulence. The transverse mixing coefficient, for example, is usually expressed in terms of the local shear velocity, u_*, and water depth, h, through the formula

$$D_T = \alpha\, u_* h \tag{1}$$

(see, e.g., Fischer, et al., 1979). The non-dimensional coefficient, $\alpha = D_T/u_*h$, obtained from laboratory and field measurements is not a constant, but varies over a range from $\alpha = 0.13$ in straight and wide open channel (Noke and Wood, 1989) to $\alpha = 3.4$ in a section of the Missouri River (Yotsukura and Sayre, 1976). The range of these value is so large that practical use of this coefficient is difficult. Attempt to correlate this coefficient with the width of the channel and the curvature of the rivers has been made by Lau and Krishnappan (1977) and

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